INTERNATIONAL STANDARDS FOR THE INDOOR ENVIRONMENT.
WHERE ARE WE AND DO THEY APPLY WORLDWIDE?

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Abstract
On the international level ISO (International Organization for Standardization), CEN (European Committee for Standardization) and ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) are writing standards related to the indoor environment. This presentation will focus on the development of standards for the indoor thermal environment and indoor air quality.

In the future, recommendations for acceptable indoor environments will be specified as classes. This allows for national differences in the requirements and also for designing buildings for different quality levels. This will require a better dialogue between the client (builder, owner) and the designer. It is also being discussed how people can adapt to accept higher indoor temperatures during summer in naturally ventilated (free running) buildings.

Several of these standards have been developed mainly by experts from Europe, North America and Japan, thus guaranteeing a worldwide basis. Are there, however, special considerations related to other parts of the world (lifestyle, outdoor climate, and economy), which are not dealt with in these standards and which will require revision?

Critical issues such as adaptation, effect of increased air velocity, humidity, type of indoor pollutant sources etc. are still being discussed, but in general these standards can be used worldwide. It is nevertheless important to take into account people's clothing related to regional traditions and season.

Keywords: Thermal comfort, indoor air quality, ventilation, standards,
Category: Indoor air quality

1. Introduction

The main purpose of most buildings and installed heating and air-conditioning systems is to provide an environment that is acceptable and does not impair health and performance of the occupants. Knowledge concerning the thermal climate parameters, their influence on the occupants and the influence of buildings and systems on these parameters is today relatively well known and established in international standards. Several factors influencing thermal comfort such as the use of increased air velocity, humidity, adaptation to higher indoor temperatures during summer in naturally ventilated (free running) buildings, and a whole-year evaluation of the indoor thermal environment are now included in the revision of international standards, e.g. ISO EN 7730 (2005) and ASHRAE Standard-55-2004 (2004).

Even though the last 15 years of research on indoor air quality have established a wealth of new information, it has still not been possible to agree on one international standard. In most existing standards or guidelines for indoor air quality, the criteria or requirements have been given as ventilation rates. The most internationally used standard for ventilation and indoor air quality is ASHRAE Standard 62.1 (2004). New concepts have been introduced in a European Technical Report, CR 1752 (1998), where criteria for indoor air quality, ventilation, thermal comfort and noise are included.

First of all, recommendations for an acceptable indoor environment are specified as classes. This allows for national differences in the requirements and also for designing buildings for different quality levels. But do we still need to take into account other differences due to climatic or personal differences?

2. Criteria for thermal comfort

The environmental parameters that constitute the thermal environment are: temperature (air, radiant, surface), humidity, air velocity and personal parameters (clothing together with activity level). Criteria for an acceptable thermal climate are specified as requirements for general thermal comfort (PMV-PPD index or operative temperature (air temperature and mean radiant temperature), air velocity, humidity) and for local thermal discomfort (draught (mean air velocity, turbulence intensity, air temperature), vertical air temperature differences, radiant temperature asymmetry, surface temperature of the floor). Such requirements can be found in standards and guidelines such as EN ISO 7730, CR 1752 and ASHRAE 55.

For most thermal parameters it has been possible to establish a relationship between the parameter and a predicted percentage of people finding the conditions unacceptable. People may be dissatisfied due to general thermal comfort and/or local thermal comfort parameters. Today no method exists for combining these percentages of dissatisfied persons to give a good prediction of the total number of persons finding the environment unacceptable. The level of thermal comfort chosen may be influenced by what is technically possible, economy, energy use, environmental pollution and performance. Individual countries or a contract between client and designer can then specify which levels must be used.

Table 1 gives recommended levels of acceptance for operative temperature and air velocity (see later) for three classes of environment. The optimal temperature (middle of range) is the same for all three classes but the acceptable range will change. For the design of heating systems and heat load calculations the lower value in the range should be used, and for cooling, the upper value. A lower class then means that the HVAC equipment can be sized smaller and requirements for room temperature control are less stringent.

The example given in Table 1 is for sedentary persons in typical summer (0,5 clo) and winter (1,0 clo) clothing. This corresponds to offices, classrooms, homes etc.

The criteria based on three classes are listed in Table 2 for local discomfort parameters (radiant temperature asymmetry, vertical air temperature differences and floor surface temperatures). Some of the classes for local thermal comfort are similar because the existing data do not support even lower limits.

Table 1: Three categories of thermal environment. Percentage of dissatisfied due to general comfort and local discomfort (ISO EN 7730, 2005, CR 1752, 1998.)

Category	Thermal state of the body as a whole		Operative temperature °C		Max. mean air velocity m/s	
	PPD %	PMV	Summer (0,5 clo) Cooling	Winter(1 clo) Heating	Summer(0,5 clo) Cooling	Winter(1 clo) Heating
A	< 6	-0.2 < PMV < + 0.2	23,5 – 25,5	21,0 – 23,0	0,18	0,15
B	< 10	-0.5 < PMV < + 0.5	23,0 – 26,0	20,0 – 24,0	0,22	0,18
C	< 15	0.7 < PMV < + 0.7	22,0 – 27,0	19,0 – 25,0	0,25	0,21

Table 2: Recommended categories for local thermal discomfort parameters

Category	Vertical air temp. diff. K	Floor surface temperature °C	Radiant temperature asymmetry K			
			Warm ceiling	Cool ceiling	Cool wall	Warm wall
A	< 2	19 - 29	< 5	< 14	< 10	< 23
B	< 3	19 - 29	< 5	< 14	< 10	< 23
C	< 4	17 - 31	< 7	< 18	< 13	< 35

2.1 Air velocity

The air velocity in a space can lead to draught sensation, but may also lead to improved comfort under warm conditions. The draught model, which is included both in ASHRAE Standard 55 and in ISO EN 7730, is listed below:

$$DR= ((34-ta)*(v-0.05)^{0.62})*(0.37*v*Tu+3.14) \quad (1)$$

where:

DR is the draught rating, i.e. the percentage of people dissatisfied due to draught;

t_a is the local air temperature in °C;

v is the local mean air velocity in m/s; and

Tu is the local turbulence intensity in per cent.

ASHRAE standard 55rev and ISO-7730rev. include a diagram to estimate the air speed required to offset an increase in temperature (Figure 1). Toftum and Melikov (2000) experimentally verified the diagram (Figure 1) for occupants having individual control (ceiling fans, openable windows). This study also showed that the requirement for personal control (open windows, personal fans) of the increased air speed is essential for acceptance. Therefore, it may not be appropriate to offset a temperature increase by increasing the air speed within a centrally controlled air system. In this case, the requirements for draught must be used.

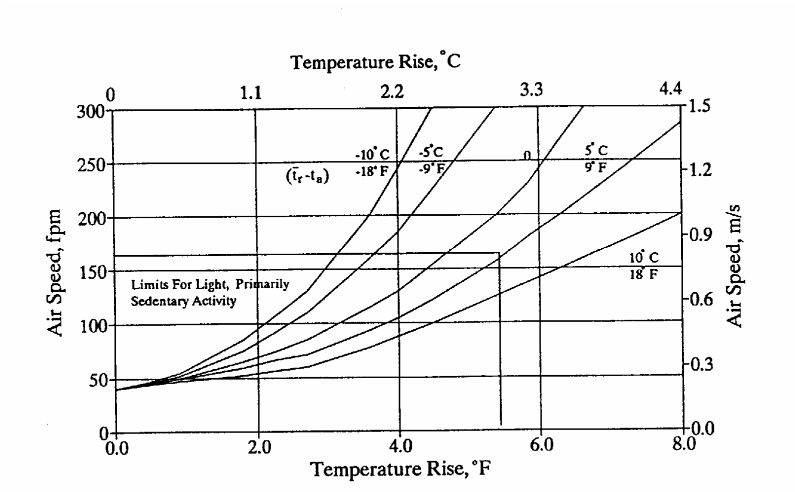

Figure 1. Air speed required to offset increased temperature (reproduced from ASHRAE Standard 55-1992rev).

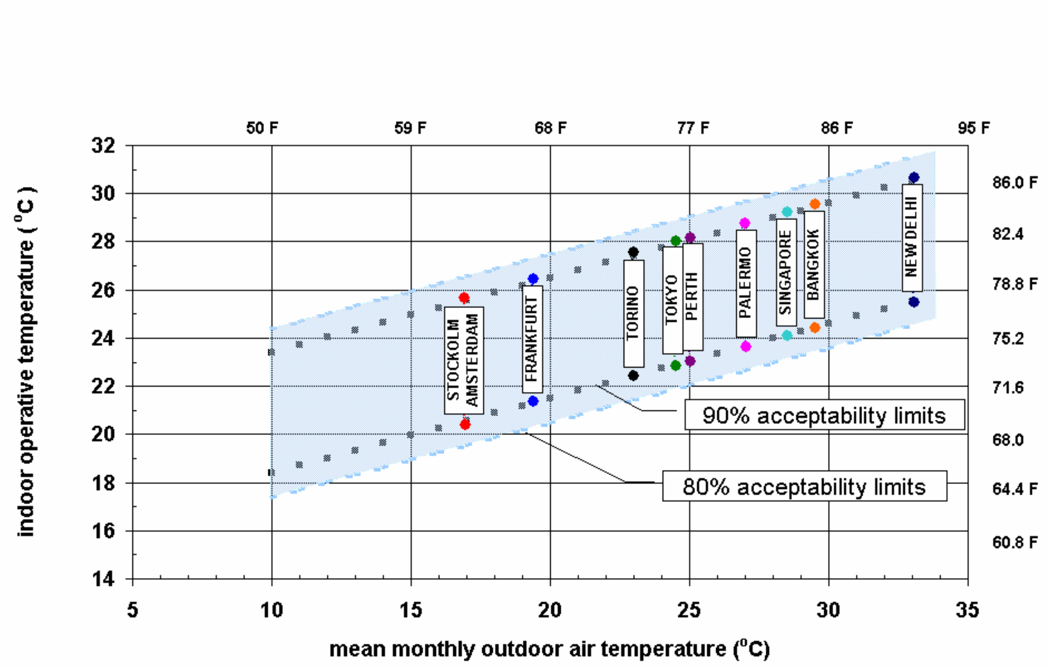

Figure 2: Acceptable operative temperature ranges for naturally conditioned spaces according to ASHRAE 55rev.-2003. Range shown for different climatic areas.

2.2 Adaptation

The above-mentioned requirements are based largely on laboratory studies with test subjects mainly from Europe and North America. But studies with Asian and African subjects (Fanger, 1973, Tanabe et al.,1987, de Dear et al., 1987) under laboratory test conditions have found similar results for general thermal comfort. Several extensive field studies summarized by de Dear and Brager (1998) show that in buildings with HVAC systems, the PMV model works well. The studies show also that in naturally ventilated buildings (free running, no mechanical cooling) people seem to adapt (behaviourally, psychologically) and can accept higher indoor temperatures than those predicted by the PMV model. In the revision of both EN ISO 7730rev and ASHRAE 55-92, it is being discussed how these results can be integrated in the standards. Whether people will still have the same level of performance at the higher temperatures is a further consideration.

The implication of this adaptive model is shown in Figure 2 for different climate zones. It is important to emphasize that the climatic data used are those of the monthly average outside air temperature. For most European cities the upper limit is 26-27°C, which is similar to the recommended limits based on the PMV-PPD index. For warmer environments, however, it will be acceptable, according to this model, to have indoor temperatures that are some degrees higher. A question is, if you have air-conditioning at home, will you then also adapt to higher temperatures in your office?

3 INDOOR AIR QUALITY AND VENTILATION

For several years ASHRAE has been working extensively on a revision of standard 62 for indoor air quality and ventilation. In the European standard organization, CEN, a working group under the technical committee TC156 "Ventilation for Buildings" has developed a technical report CR 1752 "Ventilation for Buildings: Design Criteria for the Indoor Environment" (CR1752-1998).

In most standards and guidelines the indoor air quality is related to a required level of ventilation. This is somewhat different from the concept used for the thermal environment since it has not been possible to agree on a method for specifying the level of indoor air quality in a building. Instead, required ventilation rates are specified for different types of space and occupation.

In all of the standards more than one procedure is included. They all include a prescriptive method, where the minimum ventilation rates can be found in a table listing values for different types of space, as well as an analytical procedure for calculation of the required ventilation rate. By means of the analytical procedure, the ventilation rates can be calculated on the basis of type of pollutant, emission rates and acceptable concentration. All of the proposed standards deal also with the health issue and not only the comfort issue.

3.1 Prescriptive procedure

The values in CR 1752 are given for three classes where A corresponds to ~ 15% dissatisfied, B to ~ 20% and C to ~ 30%. The basis for the ventilation rates is given in Figure 3 from CR 1752. The figure is based on studies by Berg-Munch et. al. (1986) with Danish subjects, but similar results were found by Iwashita et. al. (1990) with Japanese subjects and Cain et. al. (1983) with North-American subjects.

Studies (Fanger et. al., 1988) have shown that pollution sources in buildings emanate from occupants, building materials, furnishing and the HVAC system itself.

In CR 1752 a required minimum ventilation rate is given per person and per square metre floor area, and the values are added. However, it is permitted to design only according to the ventilation rate per person, on the assumption that the building does not emit any pollution. For the prescriptive method in the revision of ASHRAE 62rev, a minimum ventilation rate per person and a minimum ventilation rate per square metre floor area are required. The two

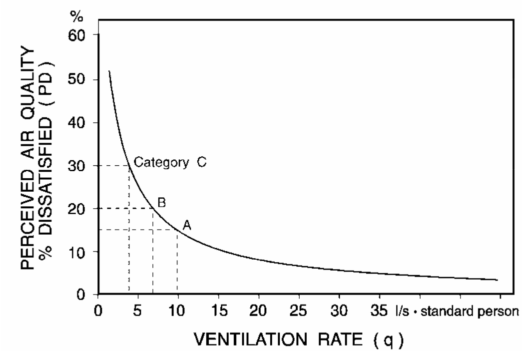

Figure 3: Dissatisfaction caused by a standard person at different ventilation rates

ventilation rates are then added. The person-related ventilation rate should take care of pollution emitted from the person (odour) and the ventilation rate based on the person's activity and the floor area should take care of emissions from the building, furnishing, HVAC system etc.

The design outdoor airflow required in the breathing zone of the occupiable space or spaces in a zone, i.e., the breathing zone outdoor airflow (V_{bz}), should be determined in accordance with the equation:

$$V_{bz} = R_p P_z + R_a A_z \qquad (2)$$

where:

A_z = Zone floor area: the net occupiable floor area of the zone m^2,

P_z = Zone population: the greatest number of people expected to occupy the zone during typical usage. Note: If P_z cannot be accurately predicted during design, it may be an estimated value based on the zone floor area and the default Occupant Density listed in Table 3.

R_p = Outdoor airflow rate required per person: these values are based on adapted occupants.

R_a = Outdoor airflow rate required per unit area.

A comparison of CR 1752 and ASHRAE standard-62 are shown in Table 3.

3.2 Analytical procedure

All of the listed standards have also an analytical procedure, either in the standard text or in an informative appendix. In this procedure the required ventilation rate is calculated on a comfort basis (perceived odour and/or irritation) as well as on a health basis. The highest calculated value, which in most cases will be the comfort value, is then used as the required minimum ventilation rate. The basis for the calculation is in all standards based on a mass balance calculation.

The required ventilation rate is calculated as:

$$Q = \frac{G}{(C_i - C_o) \cdot E_v} \quad \text{l/s} \qquad (3)$$

where G = Total emission rate mg/s
Ci = Concentration limit mg/l
C_o = Concentration in outside air mg/l
E_v = Ventilation effectiveness

In all of the standards, however, knowledge concerning emission rates (G) and concentration limits (C_i) from a health point of view, is very limited. Within the next few years, knowledge will increase and data will be available from ongoing research projects and from testing by manufacturers of building materials and furnishing.

Table 3 ASHRAE 62.1 (2003) and CR 1752 (1998)

Type of building/ space	Occu-pancy	Cate-gory	Occupants only l/s person		Additional ventilation for building (add only one) l/s·m^2			Total l/s·m^2	
	person/m^2	CEN	ASH-RAE R_p	CEN	CEN low-polluting building	CEN *Non*-low-polluting building	ASH-RAE R_a	CEN Low Pol.	ASH-RAE
Single office (cellular office)	0,1	A	2,5	10	1,0	2,0	0,3	2	0,55
		B		7	0,7	1,4		1,4	
		C		4	0,4	0,8		0,8	
Land-scaped office	0,07	A	2,5	10	1,0	2,0	0,3	1,7	0,48
		B		7	0,7	1,4		1,2	
		C		4	0,4	0,8		0,7	
Confe-rence room	0,5	A	2,5	10	1,0	2,0	0,3	6	1,55
		B		7	0,7	1,4		4,2	
		C		4	0,4	0,8		2,4	

4. DISCUSSION

Standards for the thermal environment are fairly well established and relatively consistent with each other (ASHRAE-55, ISO 7730). Fulfilling the given criteria does not, however, mean 100% acceptance. Due to individual differences it may be very difficult to satisfy everybody in a space. Individual control of the thermal environment or individual adaptation (clothing, activity) will, however, increase the level of acceptance.

In the above criteria, there are some restrictive requirements to the air velocity due to the sensation of draught. In warm environments it may be beneficial for total comfort to increase the air velocity above these levels. This effect is partly included in the use of the PMV-index. Both, ASHRAE and ISO accept an increased air velocity of up to 0,8 m/s (sedentary), but the increased air velocity must be under individual control.

Field studies have shown that for heated and air-conditioned buildings the use of the PMV-PPD index agrees with the results. But for “free running” buildings in warm climates, where it is necessary in summer to rely on natural ventilation by opening windows or using fans, there seems to be an additional adaptation that cannot be explained solely by the adaptation of clothing. It may be due partly to adaptation of activity, which is very difficult to measure in the field, and partly to another level of expectation.

A comparison between the required levels of ventilation rate in ASHRAE 62 and in CR1752 has been presented. Both standards include a prescriptive procedure, where the required minimum ventilation rate is listed in tables with values for different types of space.

Both standards include also an analytical method, where the required ventilation rate is calculated on the basis of comfort and health criteria. There is, however, very little information on acceptable comfort and/or health criteria in the standards. Furthermore, there is a lack of information on emission rates from materials and other sources. This makes it very difficult today to use the analytical methods.

CR 1752 includes the possibility of designing for different levels of perceived air quality, while ASHRAE-62.1 is a minimum standard. Therefore ASHRAE 62.1 is based on satisfying adapted persons, i.e., people who are occupying a space and have adapted to the odour level, while CR 1752 is based on un-adapted, i.e., people entering a space. The basis for the ventilation rates has been studied mainly with Scandinavian or North-American subjects. The basic ventilation rates for body odour, however, have been validated with Japanese subjects. Both documents recognize the pollution source from people and their activity, the building incl. furnishing and the HVAC system itself. There is, however, a lack of data for the building and HVAC system component, not only for Asian buildings, but also in general.

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